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ABSTRACT

Addressed to the industrial education teacher, this guide is intended to provide appropriate information, viewpoints, and attitudes regarding the metric system and to make suggestions regarding presentation of the material in the classroom. An introductory section on teaching suggestions emphasizes the need for a "think metric" approach made up of hands-on experience with the use of convenient referents (models for some of the commonly used units) but very little conversion between the metric system and the customary system. Major contents are in eight chapters: (1) The System, (2) Length, (3) Area, (4) Volume (Cubic Measure and Liter Measure), (5) Mass, (6) Volume-Mass, (7) Other Units (Temperature, Force, Energy-Work, Power, Pressure-Stress, and Torque), and (8) Miscellaneous Exercises. Each chapter includes explanatory material and a variety of suggested learning activities, some with directions addressed to the student. Some activities and exercises are of a general nature and some are related to specific occupational areas: automotive services, business machine maintenance, commercial photography, construction and building trades, drafting, electrical, graphic arts, machine shop, sheet metal, small engine repair, and mill work and cabinetmaking. A bibliography and answers to the exercises are appended. (JT)

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METRIC IMPLEMENTATION GUIDE

IMPLEMENTING THE METRIC SYSTEM

IN

INDUSTRIAL OCCUPATIONS

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F O R E W O R D

This book is intended to guide vocational-technical educators in the implementation of the metric system in the classroom. It is not an official or complete presentation and discussion of the system. Indeed, only a small portion of the metric system is appropriate for discussion in this document and for vocational-technical instruction. Books and documents are available which do present the official position for the use of the metric system in its entirety.

Through the years there have been many systems of measure labeled "the metric system," so it is important to understand which such system is meant when the term metric system is used. The U. S. Metric Conversion Act of 1975 declared that the system to be followed was the International System of Units as established by the General Conference of Weights and Measures in 1960, otherwise known as SI (Systeme Internationale). It is the SI to which professional, industrial and educational associations, governmental and educational agencies, and business enterprises are now converting.

In most countries of the world some segment of the society has used a metric system. It is likely, however, that at least some elements of that system do not conform to the SI. For example, in this country metric units have been used in the sciences and taught in science classes for years, but in large part they have been cgs (centimeter, gram, second) units, whereas the SI is a mks (meter, kilogram, second) system. This means that the dyne and other units in the cgs system are not accepted for use in the SI. The quintal (100

kilograms), used in Europe and somewhat in the U. S., is metric but is not acceptable for use in the SI. The micron (0.001 millimeter) is another example of a metric unit which is not an SI unit. The U. S. Government has formed a committee to guide in the conversion from the traditional system to the SI but it may be some time before certain practices and policies are agreed upon and adopted large-scale in this country.

In this book attention is focused primarily on SI. Secondarily, attention is given to other metric units and customary units, and their relationship to SI.

ACKNOWLEDGMENTS

One of the functions of the Mathematics Department of Illinois State University is to engage in projects which will improve the effectiveness of elementary, secondary and post-secondary, and teacher education programs. Another function is to serve the citizens of the State of Illinois. Both functions are combined in the preparation of this Metric Implementation Guide, for the guide should ease the transition to the metric system (SI) of measurement for students and those employed in industrial occupations.

Measurement is a mathematical topic, but its use in industrial occupations is best known by practitioners and educators in that field. For their assistance in gathering information for publication and for their helpful examination of drafts of this guide, the authors are deeply grateful to Claude Bell, William Johnson, Fred Kagy, Don Kimes, Dan Swanson, Robert Metzger and Ron Miller.

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Contents

	Page
Foreword	i
Acknowledgments	iii
Implementing the Metric System in Industrial Occupations	1
Teaching Suggestions	3
Hands-on Experience	3
Convenient Referents	4
Little Conversion	4
Use of This Guide	6
The System	8
Length	13
Area	20
Volume	26
Cubic Measure	26
Liter Measure	29
Mass	33
Volume--Mass	37
Other Units	39
Temperature	39
Force	41
Torque	42
Energy-Work	43
Pressure-Stress	44
Power	46
Miscellaneous Exercises	47
Other Information	49
Appendices	50
Answers	57

IMPLEMENTING THE METRIC SYSTEM IN INDUSTRIAL OCCUPATIONS

Measurement practices in the industrial occupations are changing but it is difficult to assess how soon real impact will occur. On the one hand change is occurring in the industrial occupations more rapidly than in other areas. On the other hand implementation in a given industry depends so much upon decisions about standards and codes, and the practices of other industries, that the changeover in industrial occupations may actually take longer than in other fields. Change is evident, however.

Metric fasteners are used in GM cars--color coded to alert mechanics to the need for a metric wrench. GM's Chevette is largely metric. Chrysler will produce a 1978 metric car. Effective July, 1977, purchase orders issued by Fisher Body will state quantities required in metric terms. Also at that time, invoices submitted to Fisher Body must state the actual price per kilogram. The Glass Division of PPG is changing its flat glass thickness designation to metric units.

Changes required in drafting practices are not yet completely standardized. Each company or organization has stipulated its own practices. Nevertheless, most are presently at least using dual dimensions on engineering drawings and many firms are now requiring that new parts be designed in whole millimeter dimensions if at all possible. Some firms have completely changed to metric designing. A few practices are fairly standard. Drawings will be done in millimeters.

Metric drawings are to be identified as such by marking "METRIC" near the title block and the statement "All dimensions are in millimeters, unless otherwise specified." Angle measurements require no change. A few additional details are discussed in current literature.

Little significant change will occur in small domestic engines. Bolts and other fasteners may change soon. It is likely that any new engines developed will be entirely of metric design.

The construction industry has been greatly influenced by the work of several committees in the past year. Some companies are now designating window glass thickness in metric units. Discussions with Canadian groups concerning lumber dimensions and construction modules are taking place.

About 60% of the electronic equipment and components companies are manufacturing metric products. Caterpillar is buying steel plate in metric dimensions.

Can Machinery Operations of Borden International is going metric and has developed three new all-metric machines. All new Timkin roller bearing designs have been metric for the last 10 years. General Motors Institute (GMI) will incorporate SI metric units in most engineering and engineering technology courses by Fall, 1978. Many sources now provide attachments for lathes, mills, and other machine tools which allow metric readouts in addition to the customary units.

The change to metric measurement, especially with the SI as the world-wide standard, brings with it the need for the establishment of some 20 000 international standards. This is both a problem and an opportunity. With only about 3000 of the standards now agreed upon, the U. S. has the opportunity to participate in determining standards which hopefully will reduce the number of sizes of many varieties of goods. Many of these vitally affect the industrial occupations.

Teaching Suggestions

The primary goal in teaching the metric system is--think metric. All of the activities and instructional procedures should be designed with that goal in mind. Teaching activities which are primarily lecture or teacher-focused, therefore, are inadvisable. Activities which emphasize measuring, estimating and thinking in the system are far more valuable. Filmstrips and overhead transparencies, commercially produced or otherwise, are of limited value. In fact, few of these filmstrips and transparency packets are without serious error and most are quite expensive. Worse, however, is that the use of these materials is deficient in the same way that lectures are deficient--the student is only a passive participant.

Hands-on Experience

The main emphasis of instruction should be on experiences in actually measuring, estimating and thinking metric. For example, after students become acquainted with the meter and its subunits (particularly decimeter, centimeter, and millimeter) they might use a meter tape to answer such questions as the following:

> How many meters long is the room?
>
> The window pane is how many centimeters wide?
>
> What are the centimeter dimensions of the face plate on the light switch?
>
> Unsharpened pencil lead is how many millimeters thick?

For some initial measurement activities both the object to be measured and the unit to be used should be selected by the teacher. Measurements should be reported to the nearest <u>whole</u> unit.

After some time has been spent with these measurement activities, activities in estimating lengths of various objects should be provided. The

objects to be measured and the units to be used should be varied. The emphasis should be "estimate, then check by measuring." Care should be taken to avoid precise measurements in checking. The goal is not great skill in estimating and measuring; the goal is think metric--internalize the units.

Convenient Referents

Students should look for convenient models for some of the commonly used units. It might be, for example, that the width of the nail on their little finger is about 1 cm, the distance across the back of their hand is 1 dm, or the top of their hipbone is about 1 m above floor level. Objects commonly carried in pocket or purse may provide convenient models.

The purpose of such an approach is to promote thinking metric on the part of students who have grown up learning to think in and to use the English system and who must now, in a short period of time, change and begin to think metric. Precise measurements and accurate estimates are not especially important. What is important is that the students quickly build in a set of referents which will enable them to make judgments about measurements of other objects as well as to internalize the metric system. This approach should be applied to the teaching of area, volume, and mass as well.

Little Conversion

Conversions between the metric system and the customary system should be avoided while learning the metric system. Conversions between systems can be made, when necessary, by simply consulting a table of equivalents readily available and doing the necessary multiplication or division. This is something which needs little instruction. It is appropriate, however, to make a few rough basic comparisons such as between the meter and the yard, the liter and the quart, and so on.

Conversions within the metric system, on the other hand, are quite a different matter. Converting from one metric unit to another is easily done by simply multiplying or dividing by a power of 10; a very simple task compared to converting in the customary system. Perhaps because it is so easy there is a tendency for teachers to overemphasize this activity. Some practice with conversions in the metric system is appropriate but practicing mechanical shortcuts is of questionable value. Instead, it seems more appropriate and beneficial to reason from the basic relationships between the units. Consider the following:

a. 750 grams = _____ kilogram(s)

The reasoning could be:

We have 750 grams and it takes 1000 grams to make a kilogram, so we have only 0.750 kilogram.

b. How many milliliters does a 3 liter container hold?

The reasoning might be:

The container holds 3 liters, and since 1 liter is 1000 milliliters the container holds 3000 milliliters.

Use of This Guide

This guide is addressed to the teacher. Its aim is to provide appropriate information, viewpoints, and attitudes regarding the metric system and to make suggestions regarding the presentation of the material in the classroom. A variety of activities is given and directions for some of these are addressed to the student. Nevertheless, it is not intended to be a workbook for students, nor is it intended that the activities given are sufficient or comprehensive. The attempt has been to provide examples of suitable activities designed to help the students think metric.

Several types of activities are suggested in each section. Each of these types makes a unique contribution to the learning process. It is appropriate, then, that some of each type should be provided for the student as each section is developed.

I. Measure

e.g., p. 14, exercise 1

II. Estimate and Measure

e.g., p. 27, exercise 2

III. Reasonable ("ball park") Estimates

The diameter of an aspirin tablet is _____.

(a) 3 m (b) 1 cm (c) 15 mm

IV. Metric Conversion Drill

1450 g = _____ kg

V. Applications

This guide is addressed to industrial occupational programs including Automotive Services, Business Machine Maintenance, Commercial Photography, Construction and Building Trades, Drafting, Electrical, Graphic Arts, Machine Shop, Sheet Metal, Small Engine Repair, and Millwork and Cabinet Making. Some

of the activities and exercises included are of a general nature and some are related to specific occupations. It is intended that the teacher will select from the items suggested those which are appropriate to the group of students involved and it is expected that those suggested will stimulate the creation of additional or more appropriate items by the teacher.

It must be emphasized again that the actual measurements of some of the objects given are not important. What is important is that the students have the opportunity to actively estimate and measure many objects with which they have frequent contact; that they be encouraged to "think metric."

The System

The metric system had its beginning in the latter part of the 18th century when a group of French scientists, commissioned by their government, developed a system of measurement units. The system was officially adopted by the French government in 1795, and in 1840 its use was made mandatory by the government. Over the years most of the countries of the world, including the United States, have adopted it. In 1866 the U. S. Congress passed an act making it legal but not mandatory to use the metric system in the United States. The Eleventh General Conference on Weights and Measures, meeting in 1960, adopted the International System of Units (SI)—the universally recognized metric system today. In December, 1975, HR 8674 was signed into law by President Ford, a bill that provides for the establishment of a 17-member metric board that will coordinate voluntary conversion to the SI in the U. S.

The SI is a modernized metric system of measurement with features which make it superior to the U. S. customary system and to other metric systems. One feature is that the base of the system is <u>absolute</u>; that is, force is not defined by action of gravity. An absolute system makes for simplicity of calculation. In SI units, a force of one newton gives a mass of one kilogram an acceleration of one meter per second per second. By contrast, in the European system, a force of one kilogram-force accelerates a mass of one kilogram 9.806 650 meters per second per second, and in the U. S. customary system, one pound-force accelerates a mass of one slug 32.174 feet per second per second. Another feature is <u>coherence</u>. In a coherent system any derived unit is related to any other, or to the base units, without the use of conversion factors. A third feature is that only <u>one unit</u> is used for each physical quantity. By contrast, the customary system has nine commonly used units for area, 25 units

for energy, and 26 units for length.

The SI consists of seven base units, two supplementary units, and derived units, some of which have been given special names.

Base Units

Unit	Quantity	SI Symbol
meter	length	m
kilogram	mass	kg
kelvin	temperature	K
ampere	electric current	A
mole	molecular substance	mol
second	time	s
candela	light intensity	cd

The derived units are determined by multiplying or dividing base units, without using numerical factors other than one. Some of these are shown below. For a more complete listing of these units see Appendix A or a source from Appendix C.

Some Derived Units Without Special Names

Unit	Quantity	Formula
square meter	area	m^2
cubic meter	volume	m^3
meter per second	linear velocity	m/s
kilogram per cubic meter	density	kg/m^3

Some Derived Units With Special Names

Unit	Quantity	SI Symbol	Formula
newton	force	N	$m \cdot kg \cdot s^{-2}$
pascal	pressure	Pa	N/m^2
watt	power	W	J/s
joule	energy	J	$N \cdot m$
coulomb	electric charge	C	$A \cdot s$
volt	electric potential	V	W/A
hertz	frequency	Hz	1/s or s^{-1}
ohm	electric resistance	Ω	V/A
farad	electric capacitance	F	C/V

Multiples and submultiples of these units are expressed by means of certain prefixes.* Some of the prefixes are:

Prefix	Meaning	SI Symbol
mega	1 000 000	M
kilo	1 000	k
hecto	100	h
deka	10	da
deci	0.1	d
centi	0.01	c
milli	0.001	m
micro	0.000 001	μ

*For a more complete listing of the prefixes, see Appendix A.

The prefixes have decimal meanings, i.e., each is a power of ten, and conversions among the units is facilitated by a knowledge of our numeration system.

Examples

1 hectogram	=	100 grams	(1 hg = 100 g)
1 centimeter	=	0.01 meter	(1 cm = 0.01 m)
1000 grams	=	1 kilogram	(1000 g = 1 kg)
1 meter	=	10 decimeters	(1 m = 10 dm)
1 deciliter	=	0.1 liter	(1 dL = 0.1 L)*

Not all the prefixes will be used in actual practice. Note that the SI symbol for a unit is used for both the singular and plural forms. Other established conventions for spelling, usage, etc., include:

1. Symbols for unit names are written in lower case unless they are derived from proper names. Most SI symbols for unit names are single letters (for some exceptions see Appendix A).

   RIGHT: Contents 454 g
   WRONG: Contents 454 GM

2. Periods are not used after the symbols or prefixes unless a sentence ends with such.

   RIGHT: The pencil is 16 cm long.
   WRONG: The pencil is 16 cm. long.

3. A zero digit is used in the units place when naming a number less than 1.

   RIGHT: The distance to the next road is 0.8 km.
   WRONG: The distance to the next road is .8 km.

---

*The symbol for liter as prescribed in the SI is "ℓ". In December, 1976, however, the National Bureau of Standards stated that the capital letter "L" will be used instead in the U. S. This symbol has several advantages over the "ℓ" and has been urged for adoption in the SI.

4. Numerals containing more than four digits should be separated into groups of three digits in order to facilitate reading. No commas should be used in the spaces between groups of digits.

RIGHT: The distance from the earth to the moon is about 385 000 km.
WRONG: The distance from the earth to the moon is about 385,000 km.

RIGHT: A microgram is equal to 0.000 001 g.
WRONG: A microgram is equal to 0.000001 g.

5. Prefixes are not to be used without a unit.

RIGHT: The weight lifted was 186 kilograms.
WRONG: The weight lifted was 186 kilos.

Additional information and discussion of the metric system may be found in a number of current sources (Appendix C).

Length

Until recently metric units of length have not been used extensively in the industrial occupations. In a few instances they have been used somewhat incidentally, as for example with 35 mm film. For automobiles metric units of length are used considerably, particularly with foreign imports. Except for a few such cases, however, little use has been made of the metric system in the measurement of length. This means that as the country shifts to the metric system there will be a great impact on personnel in the industrial occupations but it also means that there is now a great opportunity--the opportunity to develop nationwide and worldwide standards for a variety of items. Suitable standards and measurement units are being discussed in many different areas and there are many decisions to be made about standards for items related to the industrial occupations. Many national committees representing various sectors of our economy, industry, and labor are studying these problems. At the present time, however, very little hard conversion has taken place.

In the metric system (SI) the basic unit of length is the meter--probably the most familiar of the metric units. The meter is a little longer than the yard. Other metric units of length which are frequently used are:

kilometer--about 0.6 mile (or 7 city blocks) — 1 km = 1000 m

decimeter--the length of segment AB — 1 dm = 0.1 m

A B

centimeter--the length of segment CD — 1 cm = 0.01 m

C D

millimeter--the length of the segment to the right — 1 mm = 0.001 m

In some areas the micron is used. The micron is 0.001 mm and is a metric unit but is not part of the SI. Its use is to be discontinued.

Suggested Activities*

1. Find several objects which have approximately the measures in the chart below. Try to find things which you can easily remember or that you are frequently near. Include body measurements such as palm width, length of a finger, distance from hip to floor, etc.

1 m	1 dm	1 cm	1 mm

*The activities suggested in this book are meant to include several areas in the industrial occupations. The teacher may select from these activities those most appropriate to the subject and students being taught.

2. Use the objects listed below and others from your school or home to practice linear measurement. The main objective is to develop a better "feel" for metric units of length, and therefore rough estimates and measures are adequate. Some objects you are near frequently; the measures of these (base cabinet height, for example) you will want to remember. More than one dimension of some objects may be estimated. Check your estimates by measuring.

Object	Estimated Length	Measured Length
Pane of glass		
Concrete block		
Note pad		
Light table		
Floor tile		
Base cabinet		
16-penny spike		
Ladder		
T-square		
Tool cabinet		
Welding rod		
Piece of lumber		
Copy stand		
Bore of cylinder		
Sheet of drywall		
Film negative		
Vacuum tube		
Hacksaw blade		
Pencil		
Bolt		
_____		
_____		
_____		

The purpose in all these activities is to help foster "thinking metric." Accuracy in estimating is not crucial. Discourage students from measuring too precisely here.

3. Draw a line segment that has length

(a) 1 dm (b) 5 cm (c) 3 mm (d) 15 cm (e) 20 cm

Check by measuring. Try again with some other lengths until you are satisfied with your estimating skill.

A feel for metric units is important. Practice with estimating helps to think metric. Exercises such as the following also help. They will be of little value, however, if students do them by conversion. Instead, they should be done by just considering what is a reasonable answer. The measures given in exercises 4 and 5 and in similar exercises later in the unit are not important. Students may not know these measures nor do they need to in order to answer the questions. They should be able to rule out the inappropriate units or measures just by a general familiarity with the objects involved.

4. Supply the appropriate unit to make the sentence reasonable. Choose from mm, cm, dm, m or km.

   a. The distributor point gap on a foreign-made car is approximately 0.45 to 0.55 _____.

   b. New car manuals suggest changing oil every 12 000 _____.

   c. The wheelbase of a compact car is approximately 2.5 _____.

   d. Sheetmetal ranges from 0.1 to 6.3 _____ in thickness.

   e. An ordinary room in a house will be carpeted with a 3 x 4 _____ carpet.

   f. A common drill bit has a shaft diameter of about 6 _____.

   g. The most popular slide film has dimensions of 24 x 36 _____.

   h. A blueprint developer will accept paper up to approximately 60 _____ wide.

   i. The cylinder bore of a typical diesel truck engine is slightly under 13 _____.

   j. The pinion clearance on truck starters should range between 0.25 to 3.6 _____.

   k. A brazing rod is about 41 _____ long.

   l. A 2 x 4 has approximate dimensions of 4 x 9 _____.

   m. The thickness of a dime is 1 _____.

   n. The distance from Chicago to St. Louis is about 480 _____.

o. The width of a door might be about 0.8 _____.

p. The width of a living room might be 42 _____.

5. Choose the best answer from those provided.

a. Countertop height is approximately _____.

(1) 29 cm (2) 75 cm (3) 1 m

b. A crankcase PCV valve should be replaced every _____.

(1) 48 000 km (2) 48 m (3) 12 000 km

c. A double contact voltage regulator should be adjusted for a gap between the armature core and the armature of _____.

(1) 0.04 cm (2) 0.001 mm (3) 1 mm

d. Polyvinylchloride plastic sewer and drainage pipe has an ID of approximately _____.

(1) 10 mm (2) 10 cm (3) 10 m

e. The furniture used as spacers for setting type has a thickness of approximately _____.

(1) 0.25 cm (2) 0.6 cm (3) 0.6 mm

f. A properly sharpened drawing pencil will have about _____ of lead exposed.

(1) 3 mm (2) 3 cm (3) 10 mm

g. The gelatin film filters used were 5 _____ by 5 _____.

(1) dm (2) cm (3) mm

h. The spark plug gap for an 8-cylinder car is 0.875 _____.

(1) mm (2) dm (3) cm

i. A certain hex wrench pak contains 6 keys ranging in size from 2-6 _____.

(1) mm (2) cm (3) km

j. The axle nut on a VW is _____ wide and frequently becomes "frozen." Available now is a heavy-duty axle nut wrench for removing them.

(1) 3.6 mm (2) 36 mm (3) 36 cm

Converting between metric measures is a needed skill. It is much easier than in the customary system (yards to inches, etc.), so there is some danger of overemphasizing this activity or of emphasizing mechanical procedures. Conversions among mm, cm, dm, m and km are all that are required. Knowledge of a few basic relations of a decimal nature is sufficient for this.

10 mm = 1 cm 10 dm = 1 m 1000 mm = 1 m

10 cm = 1 dm 1000 m = 1 km 100 cm = 1 m

For example, since 1 dm = 10 cm

8.6 dm = (8.6 x 10) cm = 86 cm.

Likewise, since 1 dm = 100 mm

8.6 dm = (8.6 x 100) mm = 860 mm.

6. Complete the following:

a. _____ mm = 56 dm

b. 56 dm = _____ m

c. _____ m = 3.2 km

d. 28 cm = _____ mm

e. 28 cm = _____ m

f. 8000 m = _____ km

g. 6 m 3 dm 5 cm = _____ m = _____ cm

h. 5 cm 8 mm = _____ cm = _____ m

For "fun":

i. _____ in. = 3 yd. 2 ft. 7 in.

j. 2 yd. 1 ft. 5 in. = _____ yd. = _____ in.

7. How many 10 cm pieces can be cut from a metal bar 1.13 m long if one allows 3 mm for each saw cut?

8. There is some indication that brick will be sized 215 mm x 102.5 mm x 65 mm. If 10 mm mortar joints are used, twice the width plus a joint equals the length. Also four courses work out to a convenient depth of 30 cm, and 4 bricks laid in length with 1 cm joints will measure 90 cm. How many bricks would be needed for a brick wall that is 1.2 m high, 9 m long and 215 mm thick?

9. In the detail drawing below, how wide is the window?

Scale 1:50

10. Rivet length should be the thickness of the metal plus 1.5 times the diameter of the rivet. For riveting two sheets of metal each 1 mm thick with a rivet 2 mm in diameter how long should the rivet be?

Area

Area measurement using metric units seldom occurs at present in the industrial occupations and perhaps will be used frequently only in the building trades. Nevertheless, the concept is important for everyone and an understanding of area in metric terms is an aid to understanding volume, pressure, work, and other concepts. The initial activities here as elsewhere are designed to help think metric.

Suggested Activities

A unit of area convenient in many instances is the square centimeter: . "Square centimeter" is expressed with the symbol cm^2.

1. Make a model of a square centimeter from paper.
2. Use your model to estimate the area of each of these regions.

Figure 1

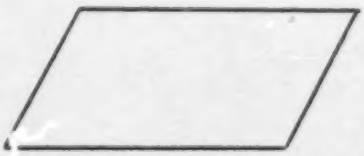


Figure 2

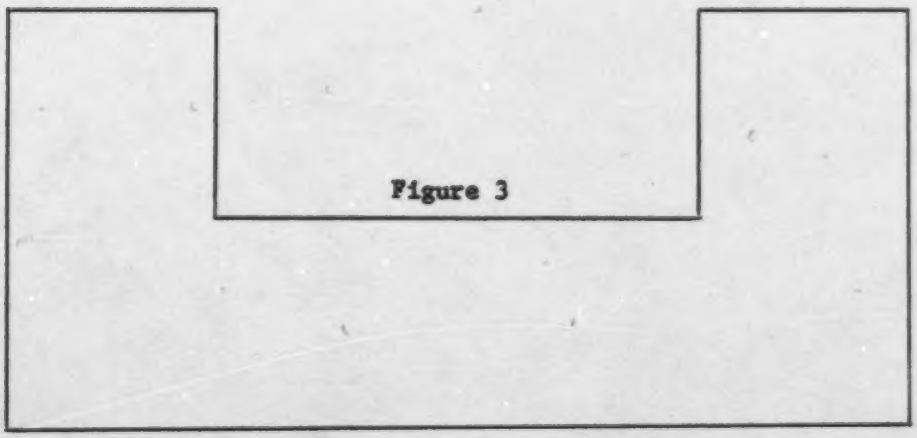


Figure 3

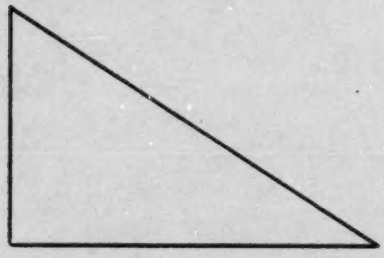


Figure 4

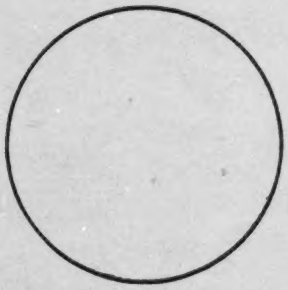


Figure 5

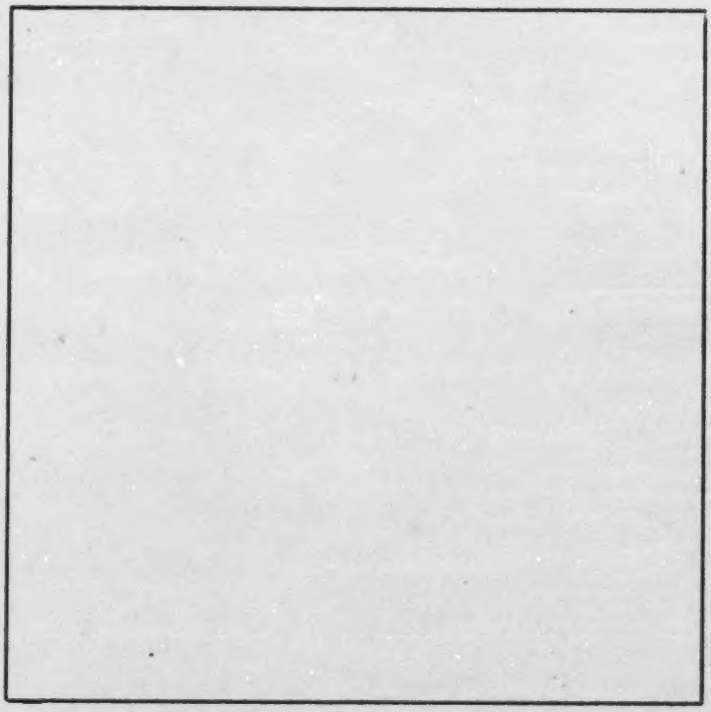
Region	Estimated Area
1	_____
2	_____
3	_____
4	_____
5	_____

The area of a rectangular region is, of course, computed by the formula $A = lw$. For example, a rectangle 2 m by 3 m has an area of 6 square meters (6 m^2); a rectangle 2 cm by 3 cm has an area of 6 cm^2; a large room 8 m by 10.5 m has an area of 84 m^2. Formulas for the area of a triangle and circle are $A = \frac{1}{2}bh$ and $A = \pi r^2$, respectively.

3. Check your estimates in number 2 by using your ruler to measure any segments needed to calculate the area.

Region	Calculated Area
1	_____
2	_____
3	_____
4	_____
5	_____

Another convenient unit of area is the square decimeter (dm^2).



4. Make a model of this square unit from heavy paper. Use your model as an aid to estimate the area of several objects. Check your estimate by measuring and calculating. Some objects are suggested; include others from your classroom, home, or place of work.

Object	Estimated Area	Calculated Area
Plywood sheet		
File cabinet		
Desk top		
Book cover		
Window pane		
Floor tile		
Workbench		
Drafting table		
Blueprint page		
Piece of sheet metal		
Photograph		
Door		
Kitchen cabinet door		
Shingle		
Radio chassis		
Bedroom		
Tennis court		

5. A square meter is a rather large unit of area. What objects can you find in your classroom that have an area of approximately:

a. 2 m^2 _____ _____

b. 4 m^2 _____ _____

c. 0.5 m^2 _____ _____

6. Supply the appropriate unit to make the sentence reasonable. Choose from cm^2, dm^2, or m^2.

a. The floor area of a house might be 150 _____.

b. This sheet of paper has an area of about 616 _____.

c. The floor of the classroom is about 38.5 _____ in area.

d. Square ceiling tile have an area of about 930 _____.

e. A gallon of a popular one-coat housepaint is guaranteed to cover 41 _____.

f. The area of a postage stamp is about 3 _____.

g. The cross-section area of a cylinder in a six-cylinder engine is about 58.5 _____.

h. An ordinary sheet of drywall has an area of slightly less than 300 _____.

7. Calculate the area of these rectangular regions:

a. 4 m x 5 m

b. 6 cm x 8 cm

c. 3.6 m x 8 m

d. 27.5 m x 7.6 m

e. 350 m x 500 m

f. 285 m x 312 m

8. Using the given dimensions for a rectangular region find the area in cm^2.

a. 4 m x 18.5 cm

b. 2 m x 3 m

c. 2.5 m x 4.2 cm

d. 22 cm x 28 cm

Find the area in m^2.

e. 420 cm x 5 m

f. 118 cm x 25 cm

g. 65 cm x 6.25 m

h. 0.5 m x 120 m

Sometimes a larger unit of area is convenient. The SI permits the use of hectare (ha) as a unit for measuring large land or water areas. 1 hectare = 10 000 m^2, so a plot 200 m by 300 m has an area of 6 ha.

9. A football field is about 49 m by 100 m (including one end zone). It has an area of about _____ m^2. Two football fields have an area of about _____ m^2. One hectare is 10 000 m^2, so two football fields have a combined area of approximately 1 hectare.

10. Find the area in hectares.

    a. 60 m x 75 m

    b. 150 000 m^2

    c. 100 m x 100 m

    d. 20 m x 1 km

A square 100 cm on each side is the same size as a square 1 m on each side. Such a square would contain 100 rows of 100 cm^2 each. Consequently 1 m^2 = 10 000 cm^2.

11. Complete the following.

    a. 3 m^2 = _____ cm^2

    b. _____ m^2 = 5000 cm^2

    c. 5 dm^2 = _____ cm^2

    d. 250 cm^2 = _____ dm^2

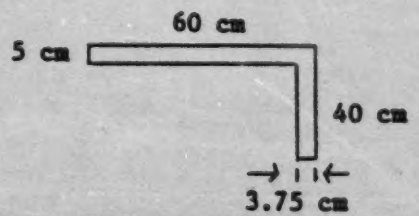
    e. 40 000 cm^2 = _____ m^2

    f. 5 cm^2 = _____ mm^2

12. A table top 120 cm by 300 cm has an area of 36 000 cm^2 or _____ m^2.

13. Each of the 5 shelves in a metal storage cabinet is 6 dm wide and 9 dm long. The total storage area of these shelves is _____ dm^2 or _____ m^2.

14. The surface area of the rafter square pictured is _____ cm^2.



15. Find the area of a floor in square yards which measures 7 ft. 7 in. by 5 ft. 6 in.

16. Find the area of a floor in square meters which measures 231 cm by 167 cm.

17. On a certain orbital sander, abrasive sheets 84 mm by 225 mm are used. The area of such a sheet is _____ mm^2 = _____ cm^2.

18. A pane of glass 25 cm by 40 cm has an area of _____ cm^2 = _____ m^2.

19. If a sheet of galvanized steel 60 cm by 240 cm costs $4.92, what is the cost per square decimeter?

20. What is the area of a cross-section (interior) of a pipe having an inside diameter of 14 mm?

21. A two-story house measures 10 m x 8.4 m. What floor space does the house have?

22. Fiberglass insulation is available in batts 38 cm wide and 120 cm long. How many such batts are needed to insulate an attic that is 3 m wide and 3.6 m long? (Assume joist spacing of 40 cm and joist thickness of 4 cm.)

23. An Illinois VOTEC bulletin recommends that for a training program in auto mechanics a "bay" for a vehicle garage have an area of approximately _____.

a. 2000 m^2 b. 3200 dm^2 c. 320 m^2

Volume

The concept of volume arises frequently in the industrial occupations. In the customary system many different units are used--bushel, peck, quart, gallon, ounce, teaspoon, tablespoon, cup--some for dry measure, some for liquid measure. Cubic units such as the cubic inch and cubic foot are also used to express volume. In the metric system, however, there are only two ways to express volume--in cubic units and in liters.

Cubic Measure

The cubic meter (m^3), cubic decimeter (dm^3) and cubic centimeter (cm^3) will be the commonly used cubic units. It is common to see "cc" used to represent "cubic centimeter." This has been the case with medicines for some time. It is also used to describe engine size for motor bikes and for automobiles--60 cc, 100 cc, 750 cc, 150 cc, etc. The proper SI symbol, however, is cm^3.

The cubic meter will be used to describe the volume of rooms or buildings. The cubic decimeter may not be used often but it plays an important role in relationships among other metric units which will be discussed later.

The formula for computing the volume of a rectangular solid is $V = lwh$ and the formula for computing the volume of a cylinder is $V = \pi r^2 h$. In these cases and in others where the volume can be computed by formula, cubic units will be used to express the volume. In many other cases the liter (discussed later) will be used.

Suggested Activities

1. a. Make a model of a cubic centimeter and cubic decimeter out of heavy paper. A suggested diagram is given in Appendix B. (Metal or wood is suitable, also.)

   b. Make a model of a cubic meter using meter sticks or similar material for edges.

   c. Challenge. Make a model of a cubic millimeter.

2. Estimate the volume of several objects in the room by thinking of cubic units--m^3, dm^3, or cm^3. Check your estimates by measuring with the cubic unit or a tape. Some objects are suggested; include others from your room, home, or place of work.

Object	Estimated Volume	Measured Volume
Tool box		
Teacher's desk		
Chalkboard eraser		
File cabinet		
Cabinet drawer		
Electrical outlet box		
Electric heater		
Oil stone		
Car battery		
Parts cleaning tank		
_____		
_____		
_____		

3. Supply the appropriate unit to make the sentence reasonable. Choose from mm^3, cm^3, dm^3, or m^3.

   a. The volume of an electric toaster is about 12 000 _____.

   b. In a darkroom the plastic developer, stop bath, and fixer tubs would each have a volume of about 5 _____.

   c. A window air conditioner might cool about 49 _____ of room space.

d. A four-cylinder foreign made compact car could have an engine size of about 2000 _____.

e. The amount of airspace in a classroom would be about 225 _____.

4. Remembering that it would take 1000 mm^3 to occupy the space of one cm^3, that 1000 cm^3 blocks occupy the space of one dm^3 and that 1000 dm^3 blocks fill one m^3, complete the following to make true sentences.

a. 1500 dm^3 = _____ m^3

b. 2 m^3 = _____ dm^3

c. 500 cm^3 = _____ dm^3

d. 4000 cm^3 = _____ m^3

e. 5 cm^3 = _____ mm^3

f. 4000 dm^3 = _____ m^3

g. 0.42 dm^3 = _____ cm^3

h. 1.491 m^3 = _____ dm^3

i. 10 000 mm^3 = _____ cm^3

j. 0.1024 dm^3 = _____ cm^3

k. 186 321 cm^3 = _____ m^3

l. 144 mm^3 = _____ cm^3

m. 250 000 mm^3 = _____ dm^3

n. 144 dm^3 = _____ cm^3

o. 144 dm^3 = _____ m^3

p. 144 cm^3 = _____ mm^3

5. A box that is 1 dm wide, 2 dm long and 1.5 dm high has a volume of _____.

a. 4.5 dm^3 b. 3000 cm^3 c. 4.5 cm^3

6. A storage cabinet in a printshop measures 100 cm by 50 cm by 30 cm. What is its volume?

7. The volume of an oscilloscope case is approximately _____ dm^3 or _____ cm^3.

8. The excavation for a house is 4 m by 9 m and is 2 m deep. How many cubic meters of material must be removed?

9. In pouring concrete for a downspout splashblock 8 dm^3 of concrete are needed. How many such splashblocks can be made from 1 m^3 of concrete?

Liter Measure

The liter is not one of the basic SI units but it is a convenient unit and is used frequently enough that it has been accepted by the SI. The liter is just a little larger than a quart and will probably be used for small to moderately sized amounts. For large amounts it seems likely that the cubic meter will be the appropriate unit. So there are two alternatives for describing measures of volume or capacity--cubic measure and liter measure. There is no set rule stipulating which of the two measures should be used in a given situation. It seems to be simply a matter of custom and convenience.

One of the nice features of the metric system is the ease with which one may change from one unit of measure to another. This pertains to the interchange between cubic measure and liter measure as well. A liter container holds exactly the same amount as a cube one decimeter (10 cm) on each edge; that is, $1\ L = 1\ dm^3$. Consequently, a 10-liter pail has a volume of 10 cubic decimeters, a 2-liter milk carton has a volume of two cubic decimeters, and a 1000-liter tank has a volume of 1 cubic meter.

Since a cube 10 centimeters on each edge contains 1000 cubic centimeters, each of these cubes is 0.001 of a cubic decimeter and hence is 0.001 of a liter. That is, one cubic centimeter equals one milliliter. In some areas, principally in medicine, the cubic centimeter and the milliliter are constantly used interchangeably.

As with other metric units, it is important to develop a feel for the metric units of liter and milliliter. Activities such as the following may help with this.

Suggested Activities

1. Estimate the capacity of each of these. Check your estimate by using water and a graduated cylinder to measure the capacities of small containers. Select some other containers familiar to you and learn their capacities.

Object	Estimated Size	Measured Size
Pop can		
Battery hydrometer		
Gasoline antifreeze can		
Paint bucket		
Developer pan		
Drinking cup		
Oil can		
_____		
_____		
_____		

2. Supply the appropriate unit to make the sentence reasonable. Choose from liter (L) or milliliter (mL).

   a. 30 _____ of Pepto-Bismol may be taken for upset stomach.

   b. Chocolate milk may be purchased in 2 _____ containers.

   c. Mary poured 100 _____ of syrup on her hotcakes.

   d. The gasoline tank of American-made mid-size cars is about 80 _____.

   e. The piston displacement of eight-cylinder automobile engines ranges from 4 to 6 _____.

   f. An automatic transmission has a fluid capacity of approximately 8 _____.

   g. It would take approximately 1200 _____ of fluid to completely fill an empty power steering unit.

   h. It would take a little over 20 _____ of coolant to fill the cooling system of a V-8 engine.

   i. Film developer is sold in containers of 996 _____.

j. The engine displacement on a gasoline power chain saw is approximately 33 _____.

k. Asbestos fibered roof coating is available in either the 4 _____ or the 20 _____ can.

l. A large drum of multipurpose grease has a volume of approximately 10 _____.

3. Choose the best answer from the ones provided.

a. A can of motor oil contains about

(1) 996 mL (2) 2 L (3) 0.5 L

b. Roof coating and driveway sealant are available in cans of approximately

(1) 5 mL (2) 1 L (3) 20 L

c. Air compressor tanks for spray paint equipment are available in volumes ranging from

(1) 50 to 130 L (2) 50 to 130 mL (3) 3 to 9 L

The liter and milliliter are probably the only liter measures that will be used in practice. Conversions between liter and milliliter are done simply by remembering that

$$1000 \text{ mL} = 1 \text{ L}$$

$$1 \text{ mL} = 0.001 \text{ L}$$

For example $258 \text{ mL} = (258 \times 0.001) \text{ L} = 0.258 \text{ L}$.

4. Complete the following.

a. 1 liter = _____ mL

b. 2000 mL = _____ L

c. 20 000 mL = _____ L

d. 0.25 L = _____ mL

e. A 10-liter bucket holds _____ mL.

f. A box which measures 10 cm on each edge has a volume of 1 _____.

g. At 4 ^{o}C one liter of distilled water weighs 1 kilogram. At that temperature _____ mL would weigh 1 gram.

h. Fractional parts of a liter are expressed in decimal form. Thus 2½ liters would be written as 2.5 L which equals _____ mL.

5. A new 12 volt auto battery comes with 2.4 liters of battery acid. Each of its six cells would need _____ mL.

6. A truck which uses 5 mL of oil per kilometer will be able to travel _____ kilometers before it uses a liter of oil.

7. Make the following conversions between cubic units and liter measures.

a. 18 cm^3 = _____ mL

b. 5 dm^3 = _____ L

c. _____ cm^3 = 250 mL

d. 18 L = _____ dm^3

e. 1.5 L = _____ m^3

f. 0.3 dm^3 = _____ mL

g. A box 2 cm by 3.5 cm by 10 cm has a volume = _____ = _____ mL.

8. A gasoline tank measures 2 dm by 5 dm by 6 dm. How many liters will it contain?

9. If you poured a liter of oil into a quart can would it overflow?

Mass

The terms mass and weight and their use have recently had considerable discussion. Mass is a quantity with an SI base unit and force is a quantity with an SI derived unit, but the term weight does not appear in SI. In science and engineering, however, the term weight has been used but a distinction between mass and weight has been carefully maintained. Currently, practices are being implemented (see Guidelines for Writers of SI Metric Standards, Appendix C) which will mean that the term weight will no longer be used in science and other technical fields. Instead, the term force of gravity will be used. In general everyday use, including the industrial occupations, no harm will occur by using the terms weight and mass synonymously.

A few metric units of mass are already used to some extent. Some canned goods and other products are available with contents designated in both customary and metric units. Large ore shipments are described in metric tons (not an SI unit); some medicine ingredients are given in milligrams. Nutritive amounts of protein, carbohydrates, fat, etc., shown on labels of food products and elsewhere, are listed in grams. Vitamin content is given in milligrams.

Some abbreviations for metric units are in current use which do not conform to SI style practices. It is common to see the symbol gm, the abbreviation Gm., and other expressions for gram. The symbol g, however, is the proper SI symbol for gram. "Kilos" is sometimes used in reference to the mass of an object, particularly in athletic weight lifting events. This incorrect and misleading usage should be avoided.

The kilogram is about 2.2 pounds--a little heavier than a box of American processed cheese. The gram, only 0.001 of a kilogram, is the approximate mass of a paper clip, and the milligram is only 0.001 gram.

Suggested Activities

1. Supply the appropriate unit to make the sentence reasonable. Choose from kilogram (kg), gram (g), or milligram (mg).

   a. The mass of a candy bar is 40 _____.

   b. A golf tee has a mass of 1 _____.

   c. Gear oil and multi-purpose grease is available in 16 _____ cans (drums).

   d. A piece of paper this size ☐ has a mass of 1 _____.

   e. The plastic drafting triangle has a mass of about 34 _____.

   f. A riding lawnmower would have a mass that ranged from 140 to 180 _____.

   g. The mass of a CB radio is approximately 2.3 _____.

   h. A package of Polaroid colorprint film has a mass of about 180 _____.

   i. The mass of a cotter pin is about 2 _____.

   j. Chain hoists are built to lift from 450 to 1800 _____.

   k. A roll of fiberglass insulation is approximately 12 m long, 10 cm thick, and 38 cm wide. It would have a mass of approximately 3.2 _____.

   l. Welding rods for arc welders are sold in packages having a mass of about 11 _____.

   m. A light towing trailer hitch will pull a trailer with a mass up to 900 _____.

   n. A gluing clamp with hard-wood jaws and steel spindle and nuts opens to 25 cm. Its mass is about 2.2 _____.

2. Choose the best answer from those provided.

   a. For chipping with an 18 mm cold chisel a _____ machinist's hammer is about the right size.

      (1) 1 kg (2) 500 g (3) 1000 mg

   b. A timing light has a mass of approximately _____.

      (1) 10 mg (2) 1 g (3) 1 kg

c. A ring shank roofing nail has a mass of approximately _____.

(1) 1 kg (2) 1 mg (3) 1 g

d. In overhauling a power mower in the small engine repair course a student replaced the spark plug. The mass of the plug was about _____.

(1) 520 mg (2) 0.5 kg (3) 52 g

3. Estimate the mass of each of the following. Check your estimates by means of a balance or scale. Some objects you are near often; the masses of these you will want to remember.

Object	Estimated Mass	Measured Mass
Hammer		
Billfold		
Pencil		
Camera		
Vacuum tube		
Paint can		
Ammeter		
Can of oil		
Brazing rod		
File		
Nickel		
Drafting scale		
Drill bit		
Nail		
Screw		
Wire cutters		
Wrench		
Chisel		
Lock washer		
Transistor		
Rivet		
Roll of romex wire		
_____		
_____		
_____		

Changing from one unit of mass to another in the metric system is easily done in the same way as with linear units. Knowing the meaning of each prefix

is all that is required.

1 milligram = 0.001 gram　　1 gram = 1000 milligrams

1 kilogram = 1000 grams　　1 gram = 0.001 kilogram

4. Complete the following.

a. 750 g = _____ kg　　d. _____ g = 2.5 kg

b. 1450 g = _____ kg　　e. 1450 kg = _____ g

c. 500 mg = _____ g　　f. 10 g = _____ mg

5. How many grams of copper, zinc, and nickel are there in 10 kg of German silver if it contains 50% copper, 20% zinc, and 20% nickel?

6. How many 250 gram boxes of cotter pins can be packaged from a carton containing 2 kilograms of pins?

7. The mass of a micrometer is about _____.

a. 300 mg　　b. 0.5 kg　　c. 120 g

Volume--Mass

One of the nice features built into the metric system is the relationship between volume and mass. For several reasons water has been used to establish this relationship: 1 dm^3 of cold water has a mass of 1 kg. (To be exact, the water should be distilled and at a temperature of 4 °Celsius.) Thus, 5 dm^3 of water has a mass of 5 kg. Furthermore, because the specific density of all other substances is related to water it is easy to find the mass of any substance if the volume of the substance is known. For example, the density of steel is 8 times that of water so 1 dm^3 of steel has a mass of 8 kg, 2 dm^3 of steel has a mass of 16 kg; alcohol is only 0.84 times as dense as water, so 1 dm^3 of alcohol has a mass of 0.84 kg, 2 dm^3 of alcohol has a mass of 1.68 kg, etc.

Since 1 dm^3 = 1 liter, 1 liter of cold water has a mass of 1 kg. Also, since 1 dm^3 = 1000 cm^3 = 1 L, 0.001 dm^3 = 1 cm^3 = 1 mL. So 1 cm^3 of cold water has a mass of 1 gram and, likewise, 1 mL of cold water has a mass of 1 gram. For larger volumes observe that 1 m^3 = 1000 dm^3, so the mass of 1 m^3 of cold water is 1000 kg or 1 megagram.

Remember that this relationship is true for cold water--not for other substances. However, 1 dm^3 of most liquids would have a mass of approximately 1 kg.

Suggested Exercises

1. 6 mL of water has a mass of 6 _____.
2. 15 g of water would have a volume of _____ mL.
3. 250 g of water has a volume of _____.
4. _____ cm = 1 dm, so _____ cm^3 = 1 dm^3.
5. _____ dm = 1 m, so _____ dm^3 = 1 m^3.

6. 1 cm^3 of cold water has a _____ g mass.

7. 1 dm^3 of cold water has a mass of _____.

8. 1 m^3 of cold water has a mass of _____ kg.

9. The water in a tank 2 m by 1 m by 1.4 m has what mass?

10. In contrast to #9, try this one: The water in a tank 2 yds. by 1 yd. by 1.4 yds. weighs how much? (Hint: One cubic foot of water weighs 62.5 pounds.)

It should be emphasized that the special volume-mass relationship in the metric system is restricted to volumes of cold water and their masses, not other substances. That is, a liter of cold water has a mass of 1 kg; a m^3 of cold water has a mass of 1000 kg; 1 milliliter of cold water has a mass of 1 gram.

To help with this understanding, the following experiment is suggested:

a. Take two containers, similarly constructed, each large enough to hold 1 liter.

b. Place the containers on opposite sides of a balance scale. Adjust the balance scale so that it balances properly. Fill one container with a liter of cold water and the other with a liter of sand. Are the scales now in balance? Does a liter of sand have a mass that is equal to, greater than, or less than a liter of cold water?

c. Repeat (b) above using a liter of sawdust or sweeping compound.

d. Repeat using a liter of developer, pop, oil, milk or some other liquid. In these cases are the masses approximately equal to that of water?

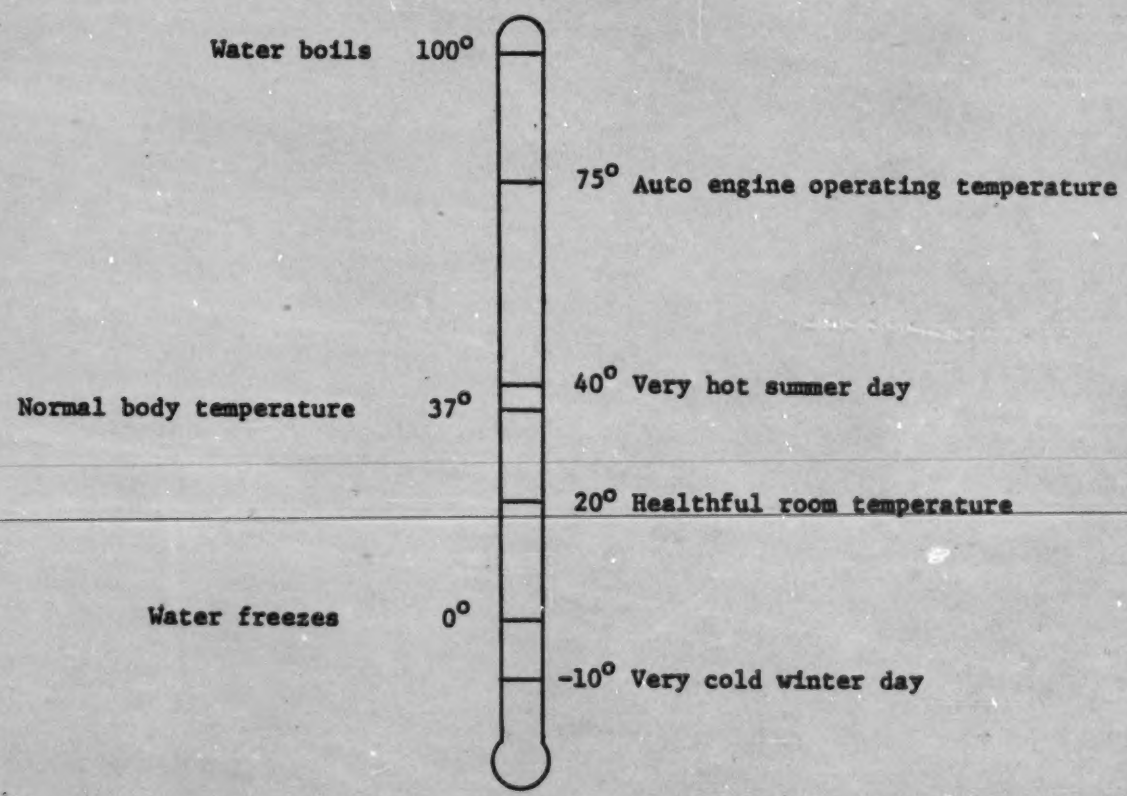
e. If the material is available, make a cube one decimeter on an edge out of cork or styrofoam. Compare the mass of this cube with that of a liter of water. (Caution: Be sure to compensate for the mass of the container holding the liter of water.)

Other Units

Several other metric units may be used to some extent in industrial occupations. A few of these are discussed here.

Temperature

The basic SI unit of temperature, the kelvin, will be used primarily in the sciences. Temperatures for most non-scientific work will be reported in degrees Celsius (°C). This is not a basic SI unit but it has been accepted for use with SI. The Celsius scale is named after the first man to use it and is identical to the centigrade scale which has been in use for many years. (The term centigrade, which is an inclination measurement of 0.01 of a right angle, should no longer be used for temperature measurements.) A few reference points on the Celsius thermometer are pictured below.


Water boils 100°
75° Auto engine operating temperature
40° Very hot summer day
Normal body temperature 37°
20° Healthful room temperature
Water freezes 0°
-10° Very cold winter day

Some industrial personnel will be concerned with some of these temperatures for heat treating and annealing of metals.

Heat Colors and Celsius Temperatures

Color	°C	Color	°C
Straw	225	Dark Red	700
Deep Straw	245	Cherry Red	900
Bronze	270	Orange Red	1100
Purple	280	Yellow White	1300
Blue	340	White Heat	1400
Black	370		

The melting point of some metals is given below.

Metal	°C	Metal	°C
Pewter	215	Silver	961
Tin	232	Gold	1063
Babbitt	239	Copper	1083
Lead	327	Iron, cast	1204
Zinc	419	Steel	1371
Magnesium	651	Nickel	1452
Aluminum	659	Iron, wrought	1482
Bronze	913	Tungsten	3399
Brass	927		

Exercises

1. Solder made of 50% lead and 50% tin is used for general work. It melts at _____.

   a. 205 °C b. 105 °C c. 520 °C

2. If a 100 Pa pressure cap is used in a car radiator, the coolant temperature can go to approximately _____ before the coolant will start to boil.

   a. 200 °C b. 120 °C c. 70 °C

3. The minimum start-to-open temperature for a thermostat in an auto cooling system is _____.

   a. 200 °C b. 120 °C c. 70 °C

4. Melamine resin is an adhesive which is cured under a hot press at _____.

   a. 40 °C b. 500 °C c. 150 °C

5. Pig iron is produced in a blast furnace at a temperature of _____.

   a. 1650 °C b. 675 °C c. 3000 °C

6. Welding arc temperatures normally are between _____.

   a. 100-200 °C b. 1000-2500 °C c. 5000-30 000 °C

Force

The SI unit of force is the newton (N). One newton is the force needed to give a mass of 1 kg an acceleration of 1 meter per second per second. In symbols this is expressed as: force (N) = mass (kg) x acceleration (m/s^2),

$$1\ N = 1\ kg \cdot m/s^2.$$

The newton is used when measuring the force needed to stretch a rubber band, to depress an automobile accelerator, to drag a box across the floor, to lift a baby, and when measuring the force of gravity. More specifically, the force needed to lift an apple is about 1 newton. Capabilities of machines or tools may be listed in newtons; a 10 000 N hoist, for example.

In the past, scientific and other technical use has differentiated between weight and mass. At the present time however, recommendations to the International Committee for Weights and Measures, and practices initiated by the American National Metric Council (ANMC) and the National Bureau of Standards

(NBS) indicate that the term weight will be avoided in scientific and other technical fields. The term force of gravity will be used instead. In everyday activities the term weight may be used synonymously with mass.

The force of gravity on an object can be approximated if its mass is known. A kilogram mass exerts a downward force on the surface on which it rests. On earth the acceleration due to gravity is about 9.8 m/s^2, so the force exerted is 1 kg x 9.8 m/s^2 or 9.8 N. Roughly then, a 1 kg mass has a force of 10 N and the gravity force on a 250 gram hamburger is about 2.5 N.

Exercises

1. What force is required to give a truck whose mass is 3500 kg an acceleration of 2 m/s^2?
2. What is the gravity force on a 450 g carpenter's hammer?

Torque

Torque is the rotational tendency caused by a force as it acts about a point. It is determined by the formula:

Torque = Force x Length of lever arm

In the metric system, force is measured in newtons and length is measured in meters so the metric unit of torque is the newton-meter; its symbol is N·m. The metric unit of energy or work, the joule, is defined in newton-meters also. By taking care to express work and energy in joules only and torque in newton-meters there will be no confusion.

Torque is involved when tightening a jar lid, turning a screw with a screwdriver or tightening a nut with a wrench. A torque of 3 N·m would be likely when using a screwdriver. Tightening spark plugs might require a torque of 40 N·m. Larger measures of torque can be expressed using the usual prefixes;

e.g., kN·m. The engine of a large car might develop a torque of 0.5 kN·m.

Torque wrenches are available with several different scales, including some which are calibrated in kilogram-meters. Soon, only those calibrated in newton-meters should be used. Existing wrenches may be recalibrated by taping on a new scale.

Exercises

1. A torque wrench with a handle of length 60 cm is pulled with a force of 600 N. How much torque is applied?
2. For tightening head bolts a torque of _____ N·m would be applied.
   a. 10 b. 130 40
3. The engine of a small car develops a torque of about _____ N·m.
   a. 40 b. 100 c. 160

Energy-Work

The metric unit of work, energy, and quantity of heat is the joule (J). Both work and energy are computed by multiplying force and distance. This product would be expressed in newton-meters (N·m). Torque is also the product of force and distance but is rotational rather than linear. To distinguish between the linear and rotational action of the force involved, the joule is used as the unit of work and the newton-meter is reserved as the unit of torque.

In the customary system there are several units of energy but those most commonly used are the calorie, the kilocalorie ("large" calorie), kilowatt hour, and British Thermal Unit (BTU). The calorie is used primarily as a measure of heat energy and the large calorie is used for food energy. In the metric system (SI), the joule will be used for all measures of energy. Since the joule is rather small, the kilojoule (kJ) and megajoule (MJ) are likely to be used. For example, consider their use in energy consumption.

Refrigerator per day	18 MJ
Range per meal	5.4 MJ
Oven per hour	1.8 MJ
Toaster per slice	18 kJ
Iron per hour	3.6 MJ
Water heater per day	43.2 MJ
Color TV per hour	1.18 MJ
100 watt bulb per hour	360 kJ
Hair dryer per hour	1180 kJ

The energy usage of these items is currently measured in kilowatt hours. The kilowatt hour is a measure of work which is accepted in the SI but its use should not be extended beyond the present uses. Instead the megajoule should be used. Note that 1 kwh = 3.6 MJ.

Energy sources are of frequent concern in welding where the term heat is usually used instead of energy. A few examples follow:

> 1000 joules of heat is generated in the spot welding of two sheets of 1 mm thick steel that requires a current of 10 000 amperes for 0.1 second.
>
> About 1380 J are required to heat and melt 1 g of steel.
>
> In an oxyacetylene torch with an orifice flow rate of 28 L/min, the total heat available would be 25 kJ/s. Only 8.8 kJ/s is available at the torch tip.
>
> When heating or melting a metal with a laser beam, the concept of energy absorbed per unit of volume is important. The energy absorbed can be written in dimensions of joules per cubic millimeter (J/mm^3).

Pressure-Stress

The SI unit for pressure is the pascal. It is the force of one newton per square meter (N/m^2). Thus, it is a measure similar to the conventional pound per square inch (psi). The pascal is a rather small unit of pressure.

Imagine that 100 mL of water was poured evenly on a surface of one square meter. The layer of water would be very thin—only about 0.1 mm. The force exerted, one pascal, is quite small. Consequently, the kilopascal (kPa) will be frequently used. Some common pressures are

Atmosphere	101 kPa
Automobile tire	200 kPa
City water	280 kPa
Ten-speed bike tire	400 kPa
Auto hydraulic brake system	30 000 kPa (30 MPa)
Comprssed air	700 kPa
Manifold vacuum	70 kPa

Some units of pressure which will be discontinued are pounds per square inch, centimeters of water, inches of mercury, millimeters of mercury, and the bar.

1 cm of water	= 98 Pa
1 in. Hg	= 3.4 kPa
1 mm Hg	= 133 Pa
1 bar	= 100 kPa
1 millibar	= 100 Pa
1 psi	= 6.9 kPa

Exercise

1. Railroad car wheels are forced-fit onto their axles under pressures of 1400-2000 _____.

   a. Pa b. kPa c. MPa

Power

Many different units of measure are now used to measure power. Some of them are BTU/h, cal/m, erg/s, ft·lb/h, horsepower, and ton of refrigeration. In the SI, there is only one unit of power—the watt (W). The watt is used as the unit of mechanical, electrical, and thermal power. The output of all power-producing devices will be expressed in watts; electric motors, gasoline engines—even auto engines. Also the power input required to operate some devices will be expressed in watts. A few basic formulas show the relationships among the newton, joule and watt:

Energy (J) = work done

= force (N) x distance (m)

1 J = 1 N·m

Power (W) = rate of doing work (J/s) = $\frac{\text{energy supplied}}{\text{time (s)}}$

1 W = 1 J/s = 1 N·m/s

In order to supply 540 joules of energy in 9 seconds, the power required is

$$\frac{540\ \text{J}}{9\ \text{s}} = 60\ \text{W}\ .$$

For larger quantities of power, kilowatt (kW) and megawatt (MW) are used.

Exercises

1. An electric heater supplies heat energy of 8 megajoules over a one-hour period. What power is required?
2. A medium duty portable electric drill will deliver how much power?

   a. 300 W b. 300 kW c. 3 MW
3. A moderately priced rotary gas powered lawn mower has _____ of power.

   a. 250 W b. 1 kW c. 2 MW

Miscellaneous

1. Draw a plot plan of a house lot with a scale of 1:500 (2 mm = 1 m) using metric units.
2. Draw a plot plan of an athletic field (football, for example) with a scale of 1:1000 using metric units.
3. A 1500 m race is run in 3.8 minutes. What was the speed in km/h?
4. A saw blade has 50 teeth per decimeter of length. How many teeth per centimeter does it have?
5. A buckle folding machine makes two folds in a piece of paper, the folds being made at right angles to each other. If a piece of paper 42.8 cm by 70 cm is used in this machine,
   a. what are the dimensions of the folded piece?
   b. what is the area of the folded piece?
6. A can with a volume of 5000 cm^3 has a capacity of _____ liters.
7. If the water in a container has a mass of 3500 g, how many liters of water are in the container?
8. The length of a runway is 1.575 km or _____ m.
9. A standard doorway is about _____ high.
10. Standard stud spacing is _____.
11. The volume of a sharpening stone 18 cm by 5 cm by 2.5 cm is _____.
12. A certain type metric feeler gauge has 35 blades ranging from 0.04 _____ to 0.89 _____.
    a. cm, cm b. mm, mm c. m, m
13. The 12.5 cm heavy-duty mechanic's vise has a mass of about 22 _____.
    a. g b. mg c. kg
14. The mass of a curved claw hammer is about _____.
    a. 0.5 kg b. 5000 g c. 16 g

15. The maximum capacity of the anti-freeze tester is 10 _____.

    a. L b. mL c. dL

16. One of the large steel company's blast furnaces has a hearth diameter of 13.7 _____ and its top gas temperature will be about 1600 ^{o}C.

    a. cm b. m c. km

17. Approximately 114 _____ of copper and zinc ore must be mined in order to get the 1000 g of brass needed to make one trumpet.

    a. cg b. g c. kg

18. On an automobile trip of 576 km, a traveler used 76 L of gas. The fuel consumption for this trip was _____ km/L.

Other Information

1. Some manufacturers of glass are beginning to designate flat glass thickness in metric units. For example, what has been designated as 1/8 inch glass will be listed as 3 mm glass.

2. A half-inch bolt and a 12-millimeter bolt are very close to the same size. In order to prevent stripping a thread or ruining a casting the proper tool should be selected.

3. To identify tools in the shop that are metric, the tools will be colored yellow.

4. The Chevette is of metric design.

   Engine displacement: 1.4 or 1.6 liters

   Body dimensions: 1544 mm x 4031 mm

   Wheelbase: 2394 mm

   Mass: 867 kg

   Fuel capacity: 49 liters

   Tire pressure: 44 kPa

   Tires for the Chevette are a new, nearly all metric, design: P155/80 B 13. 155 indicates a cross section diameter of 155 mm and 80 is the cross section height/width ratio. To conform to existing rim sizes, the bead diameter is 13 inches.

Appendix A

The Supplementary Units

Unit	Quantity	SI Symbol
radian	plane angle	rad
steradian	solid angles	sr

The Derived Units with Special Names

Unit	Quantity	SI Symbol	Definition
newton	force	N	$m \cdot kg \cdot s^{-2}$
pascal	pressure	Pa	N/m^2
watt	power	W	J/s
joule	energy	J	N·m
coulomb	electric charge	C	A·s
farad	electric capacitance	F	C/V
henry	inductance	H	V·s/A
hertz	frequency	Hz	1/s or s^{-1}
lumen	luminous flux	lm	cd·sr
lux	illuminance	lx	lm/m^2
ohm	electrical resistance	Ω	V/A
siemens	conductance	S	A/V
tesla	magnetic flux density	T	Wb/m^2
volt	electric potential	V	W/A
weber	magnetic flux	Wb	V·s

The Derived Units without Special Names

Unit	Quantity	SI Symbol
square meter	area	m^2
cubic meter	volume	m^3
meter per second	linear velocity	m/s
radian per second	angular velocity	rad/s
meter per second squared	linear acceleration	m/s^2
radian per second squared	angular acceleration	rad/s^2
newton-meter	moment of force	N·m
kilogram per cubic meter	density	kg/m^3
joule per kelvin	entropy	J/K
watt per square meter	thermal flux density	W/m^2

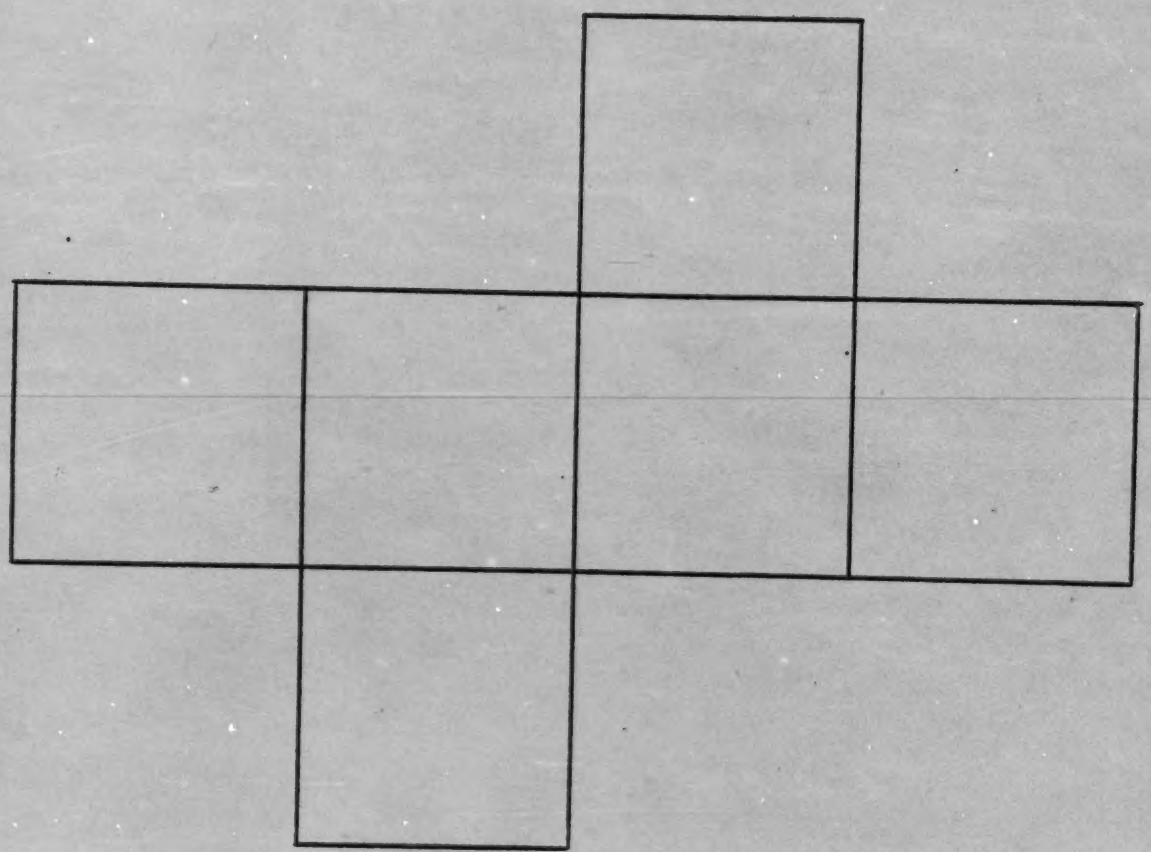
Prefixes

Names of multiples of SI and metric units are formed by using prefixes with "meter", "gram", "liter", "watt", or any other unit. Symbols use a prefix letter such as "ns" for nanosecond, "kHz" for kilohertz, "mV" for millivolt, etc.

giga	G	10^9	1 000 000 000	one billion
mega	M	10^6	1 000 000	one million
kilo	k	10^3	1 000	one thousand
hecto	h	10^2	100	one hundred
deka	da	10^1	10	ten
—	—	10^0	1	one
deci	d	10^{-1}	0.1	one tenth
centi	c	10^{-2}	0.01	one hundredth
milli	m	10^{-3}	0.001	one thousandth
micro	μ	10^{-6}	0.000 001	one millionth
nano	n	10^{-9}	0.000 000 001	one billionth
pico	p	10^{-12}	0.000 000 000 001	one trillionth

Appendix B

Suggested Diagram for Paper Cubes



Appendix C

Sources of Information

American National Standards Institute (ANSI), 1430 Broadway, New York, New York 10018.

Metric Editorial Guide, American National Metric Council, 1625 Massachusetts Avenue, N.W., Washington, D.C. 20036.

Guidelines for Writers of SI Metric Standards and Other Documents, Lou Perica, 1975, American National Metric Council, 1625 Massachusetts Avenue, N.W., Washington, D.C. 20036.

Guidance for Using the Metric System--SI Version, Valerie Antoine, Society of Technical Communication, 1010 Vermont Avenue, Washington, D.C. 20005.

Metric Practice Guide and Style Manual, National Bureau of Standards, from AMJ Publishing Company, Tarzana, California 91356.

Metric Guide for Educational Materials, American National Metric Council, 1625 Massachusetts Avenue, N.W., Washington, D.C. 20036.

The International (SI) Metric System and How It Works, Robert Hopkins, 1974, Polymetric Services, Tarzana, California 91356.

American Metric Journal. Published bimonthly by AMJ Publishing Company, P.O. Box 696, Tarzana, California 91356.

Metric Bulletin. Published by J. J. Keller and Associates, Inc., 145 W. Wisconsin Avenue, Neenah, Wisconsin 54956.

Metric Reporter. Published biweekly by the American National Metric Council, 1625 Massachusetts Avenue, N.W., Washington, D.C. 20036.

Metric News. Published bimonthly by Metric News, Inc., 830 North 109th Street, Milwaukee, Wisconsin 53226.

Recommended Practice for the Use of Metric (SI) Units in Building Design and Construction, NBS Technical Note 938, April 1977, U. S. Government Printing Office, Washington, D.C. 20402.

A variety of Vocational-Technical Instructional Packages are available from the Center for Vocational Education, The Ohio State University, 1960 Kenny Road, Columbus, Ohio 43210.

A series of booklets, Going Metric in Industrial Education, is available from IET/BGSU, Curriculum Laboratory, Department of Industrial Education and Technology, Bowling Green State University, Bowling Green, Ohio 43403.

A series of booklets, Transition to Metric, is available from Motor Vehicle Manufacturers Association, Uniten Systems, 246 W. 34th Street, Indianapolis, Indiana 46208.

A series of booklets, Taking the Tricks out of Metrics, may be ordered from Creative Universal, Inc., 3050 E. Outer Drive, Detroit, Michigan 48234.

Industrial Occupations Sources

ASTM Standard for Metric Practice (ASTME 380-76), 1976, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

John Deere SI Information, John Deere Product Engineering Center, P.O. Box 270, Waterloo, Iowa 50704.

Going Metric--Application of the Metric System in the Marketing of Paper, American Paper Institute, 260 Madison Avenue, New York, New York 10016.

SI Metric Guide for Heating, Refrigerating, Ventilating and Air Conditioning, ASHRAE, Inc., 345 E. 47th Street, New York, New York 10017.

Metric Practice Guide for the Welding Industry, American Welding Society, 2501 N. W. 7th Street, Miami, Florida 33125.

Welding Handbook, Vol. I, Fundamentals of Welding, American Welding Society, 2501 N. W. 7th Street, Miami, Florida 33125.

Articles

"Metric Measurement in Vocational and Technical Education: An Inservice Manual," Joseph Pokorney and Richard Hofstrand, Illinois Career Education Journal, Summer-Autumn, 1975, pp. 35-36.

"Chain Breaker in English or Metric," John Krape, School Shop, February, 1976, pp. 46-47.

"A Dollars-and-Sense Approach Can Swing the Switch to Metric," Clarence H. Preitz and Andrew Clark, School Shop, June, 1976, pp. 18-19; 21.

"Designing a Metric Gas Container," David W. Mead, School Shop, January, 1976, pp. 29-30.

"Going Metric in Industrial Arts," James M. Cassetto, American Vocational Journal, January, 1976, pp. 36-39, 48.

"GM Updates Drafting Standards to Include SI Metric," George E. Rowbotham, Metric News, March/April, 1977, pp. 12-14.

"Third Angle Projection for Engineering Drawings," Richard Thorman, Metric News, November/December, 1976, p. 24.

Booklets and Catalogs

"An Educator's Guide to Teaching Metrication," Consumer Information Services, D703, Sears, Roebuck and Company, Sears Tower, BSC 40-22, Chicago, Illinois 60684.

"Drafting and Graphic Arts Equipment," Modern School Supply, Reader Service Department, Industrial Education, P.O. Box 2531, Clinton, Iowa 52732.

"Adams Tool and Supply Company Goes Metric," 1360 W. Armitage Avenue, Chicago, Illinois 60622.

"America Goes Metric," America's Metric Supply House, Central Instrument Company, 900 Riverside Drive, New York, New York 10032.

"Industrial Arts Education for US Metric Study," Orville Nelson, Center for the Improvement of Learning and Instruction, Stout State University, Menomonie, Wisconsin 54751.

Appendix D

Standards Committees

ISO--The International Organization for Standards is an international, non-governmental agency for standards which is comprised of national standards bodies of about 80 nations.

ANSI--The American National Standards Institute is a federation of some 180 trade associations, technical societies, labor unions, and about 900 company members. ANSI is the U. S. member of ISO. ANSI does not write standards. It reviews and approves proposed standards written by committees administered by many technical and trade associations after all concerned groups have accepted them.

The address for ANSI is 1430 Broadway, New York, New York 10018. Current information about developments within specific trade associations is found in journals such as:

Metric News. Published bimonthly by Metric News, Inc., 830 North 109th Skreet, Milwaukee, Wisconsin 53226.

Metric Bulletin. Published monthly by J. J. Keller and Associates, Inc., 145 W. Wisconsin Avenue, Neenah, Wisconsin 54956.

Metric Reporter. Published biweekly by the American National Metric Council, 1625 Massachusetts Avenue, N.W., Washington, D.C. 20036.

American Metric Journal. Published bimonthly by AMJ Publishing Company, P.O. Box 696, Tarzana, California 91356.

Answers

Pages 16–19

4. a. mm
   b. km
   c. m
   d. mm
   e. m
   f. mm
   g. mm
   h. cm
   i. cm
   j. mm
   k. cm
   l. cm
   m. mm
   n. km
   o. m
   p. dm

5. a. 1 m
   b. 48 000 km
   c. 1 mm
   d. 10 cm
   e. 0.6 cm
   f. 10 mm
   g. cm; cm
   h. mm
   i. mm
   j. 36 mm

6. a. 5600
   b. 5.6
   c. 3200
   d. 280
   e. 0.28
   f. 8
   g. 6.35; 635
   h. 5.8; 0.058
   i. 139
   j. $2\frac{17}{36}$; 89

7. 11
8. 1280
9. 1.5 m
10. 5 mm

Pages 21-25

3.

Region	Calculated Area	Region	Calculated Area
1	8 cm^2	4	9.6 cm^2
2	8 cm^2	5	12.6 cm^2
3	57 cm^2		

6. a. m^2
   b. cm^2
   c. m^2
   d. cm^2
   e. m^2
   f. cm^2
   g. cm^2
   h. dm^2

7. a. 20 m^2
   b. 48 cm^2
   c. 28.8 m^2
   d. 209 m^2
   e. 175 000 m^2
   f. 88 920 m^2

8. a. 7400
   b. 60 000
   c. 1050
   d. 616
   e. 21
   f. 0.295
   g. 4.062 5
   h. 60

9. 4900; 9800

10. a. 0.45
    b. 15
    c. 1
    d. 2

11. a. 30 000
    b. 0.5
    c. 500
    d. 2.5
    e. 4
    f. 500

12. 3.6

13. 270; 2.7

14. 431.25

15. About 4.63

16. About 3.86

17. 18 900; 189

18. 1000; 0.1

19. $0.034

20. About 154 mm^2

21. 168 m^2

22. About 23

23. 3200

Pages 27-28

3. a. cm^3
   b. dm^3
   c. m^3
   d. cm^3
   e. m^3

4. a. 1.5
   b. 2000
   c. 0.5
   d. 0.004
   e. 5000
   f. 4
   g. 420
   h. 1491
   i. 10
   j. 102.4
   k. 0.186 321
   l. 0.144
   m. 0.250
   n. 144 000
   o. 0.144
   p. 144 000

5. 3000 cm^3

6. 150 000 cm^3

7. Varies

8. 72

9. 125

Pages 30-32

2. a. mL
   b. L
   c. mL
   d. L
   e. L
   f. L
   g. mL
   h. L
   i. mL
   j. mL
   k. L; L
   l. L

3. a. 996 mL
   b. 20 L
   c. 50 to 130 L

4. a. 1000
   b. 2
   c. 20
   d. 250
   e. 10 000
   f. L
   g. 1
   h. 2500

5. 400

6. 200

7. a. 18
   b. 5
   c. 250
   d. 18
   e. 0.0015
   f. 300
   g. 70 cm^3; 70

8. 60

9. Yes

Pages 34-35

1. a. g
   b. g
   c. kg
   d. mg
   e. g
   f. kg
   g. kg
   h. g
   i. g
   j. kg
   k. kg
   l. kg
   m. kg
   n. kg

2. a. 500 g
   b. 1 kg
   c. 1 g
   d. 52 g

Page 36

4. a. 0.750
   b. 1.45
   c. 0.5
   d. 2500
   e. 1 450 000
   f. 10 000

5. 5 kg of copper; 2 kg of zinc; 2 kg of nickel

6. 8

7. 120 g

Pages 37-38

1. g

2. 15

3. 250 mL

4. 10; 1000

5. 10; 1000

6. 1

7. 1 kg

8. 1000

9. 2800 kg

10. About 4725 pounds

Pages 40–41

1. 205 °C

2. 120 °C

3. 70 °C

4. 150 °C

5. 1650 °C

6. 5000–30 000 °C

Page 42

1. 7000 N

2. 4.5 N

Page 43

1. 360 N·m

2. 130

3. 160

Page 45

1. MPa

Page 46

1. 2.2 kW

2. 300 W

3. 250 W

Pages 47–48

3. About 24

4. 5

5. a. 35 cm by 21.4 cm b. 749 cm^2

6. 5

7. 3.5

8. 1575

9. 2 m

10. 40 cm

11. 225 cm^3

12. mm; mm

13. kg

14. 0.5 kg

15. mL

16. m

17. kg

18. 7.6